

Changing Supercycle of the ER UMa-Type Star V1159 Ori

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Abstract

We examined the VSNET light curve of the ER UMa-type star V1159 Ori. We detected a large variation of the supercycle (the interval between successive superoutbursts) between extremes of 44.6 and 53.3 d. The outburst activity was also found to decrease when the supercycle was long. The observed variation of the supercycle corresponds to a variation of $\sim 40\%$ of the mass-transfer rate from the secondary star, totally unexpected for this class of objects. We also detected a hint of ~ 1800 d periodicity in the variation, whose period is close to what has been suggested for solar-type cycles for cataclysmic variables (CVs). If this periodicity is caused by the magnetic activity of the secondary star, this detection constitutes the first clear evidence of continuing magnetic activity in CV evolution, even after crossing the period gap. This activity may partly explain still poorly understood origins of the high mass-transfer rates in ER UMa-type stars.

Key words: stars: cataclysmic variables — stars: dwarf novae — stars: individual (V1159 Ori)

1 Introduction

ER UMa stars are a subgroup of SU UMa-type dwarf novae (for a review of dwarf novae, see Osaki (1996)), whose known members are ER UMa, V1159 Ori, RZ LMi, and DI UMa. The most striking feature of ER UMa stars is the extremely short recurrence time (19–45 d) of superoutbursts (Kato, Kunjaya (1995); Nogami et al. 1995a,b; Robertson et al. (1995); Misselt, Shafter (1995); Kato et al. (1996)). Another striking feature of ER UMa stars is the stability of supercycles, both in their lengths and outburst pattern. The best exemplification of this stability can be seen in folded light curves and $O - C$ figures presented in Robertson et al. (1995). The extremely short supercycle length and the stability of the outburst patterns are basically explained, within the framework of the disk-instability model, as a result of constant high mass-transfer rates from the secondary Osaki (1995a). The mass-transfer rates in SU UMa-type dwarf novae are generally considered to be confined to a small range determined by angular-momentum removal by the gravitational wave

Table 1: Superoutbursts of V1159 Ori.

JD start	Cycle number	JD start	Cycle number
2449982	0	2451110	25
2450072	2	2451157	26
2450118	3	2451202	27
2450161	4	2451249	28
2450340	8	2451295	29
2450386	9	2451399	31
2450431	10	2451450	32
2450475	11	2451501	33
2450523	12	2451559	34
2450574	13	2451614	35
2450665	15	2451667	36
2450714	16	2451759	38
2450759	17	2451812	39
2450803	18	2451853	40
2450850	19	2451896	41
2450892	20	2451942	42
2451030	23	2451987	43
2451070	24		

radiation. The origin of high-mass transfer rates in ER UMa stars is still an open question. Some models assume irradiation effect from a hot white dwarf, which may be the result of a hypothetical recent nova eruption (the possibility was originally raised by Nogami et al. 1995b, see also Patterson (1998)). An examination of any secular changes in the supercycle in these systems would provide an essential clue for testing these hypotheses.

2 Observation and Analysis

We examined the observations posted to VSNET (<http://www.kusastro.kyoto-u.ac.jp/vsnet/>), and found an appreciable change in one of the ER UMa stars, V1159 Ori. The object has been very well sampled by many observers around the world since 1995 September (figure 1).

The time of the start of a superoutburst was defined as its mid-rising branch. Although occasional observational gaps introduced an uncertainty of 1–2 d, most of these superoutbursts were well sampled and the times were usually determined within an uncertainty of 1 d. Table 1 lists the observed times of superoutbursts. The cycle number (E) represents number of supercycles since the JD 2449982 superoutburst.

A regression to these times has yielded a linear ephemeris of $2449962.9 + 46.82E$. The derived supercycle length of 46.82 d is slightly longer than the 44.5 d

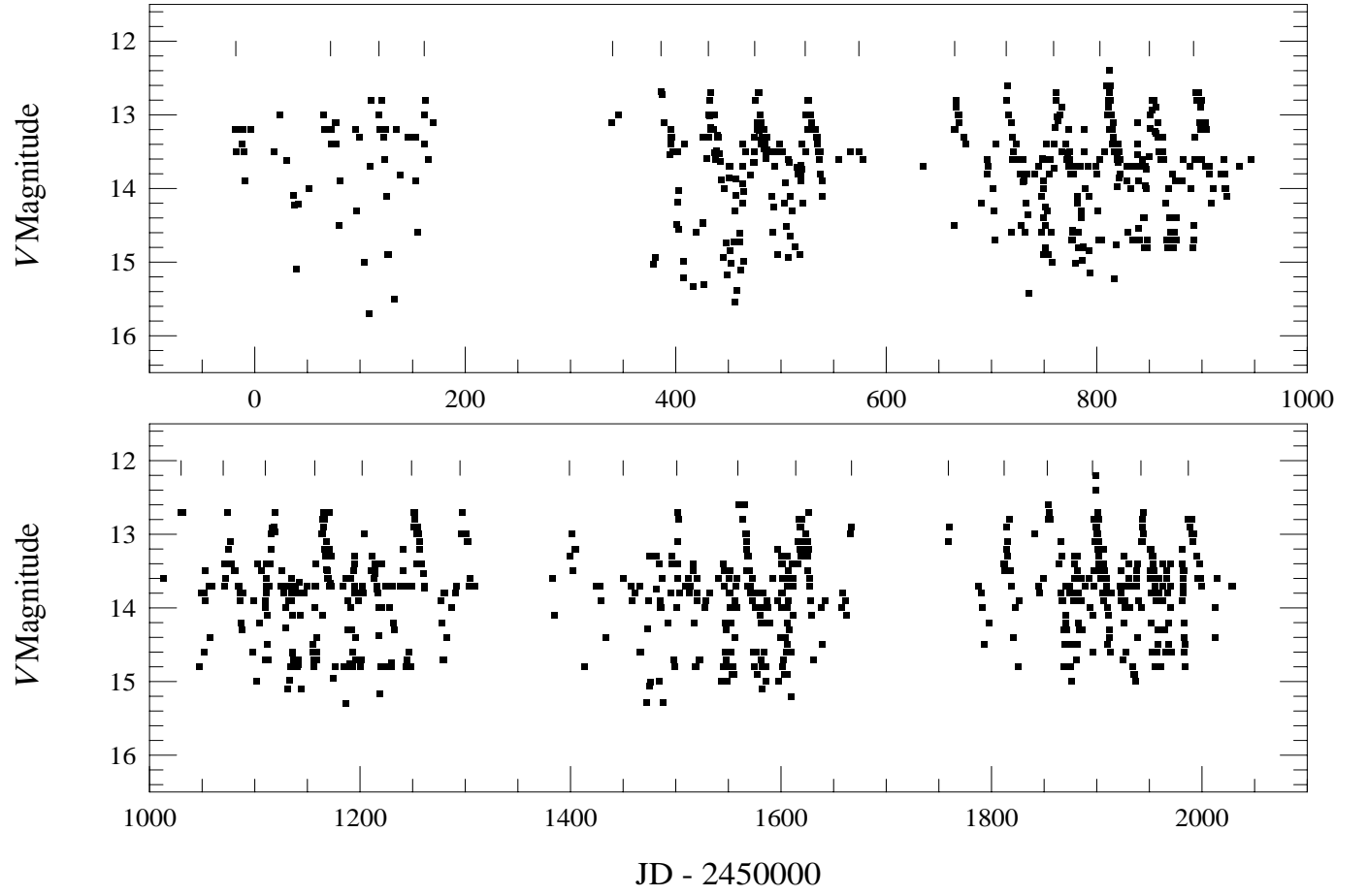


Figure 1: Light curve of V1159 Ori from VSNET observations. The ticks represent the start of superoutbursts, as listed in table 1

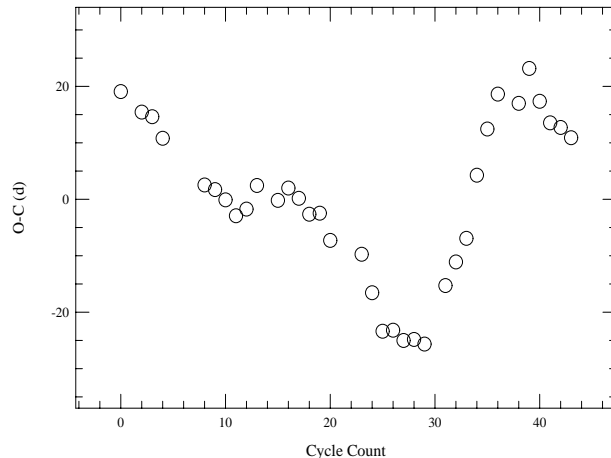


Figure 2: $O - C$ diagram of V1159 Ori superoutbursts.

by Robertson et al. (1995). Figure 2 shows the $O - C$ diagram against this ephemeris. The most remarkable feature is the presence of large $O - C$ changes compared to Robertson et al. (1995). This large change is mainly caused by an increase in the supercycle length between $E = 29$ and $E = 36$, corresponding to the period between 1999 May and 2000 May. The supercycle during interval is 53.3 d, which is 14% longer than the long-term average. Such a large change in supercycle has not been seen in ER UMa.

3 Discussion

The long-term average of the supercycle lengths in V1159 Ori, being close to the minimum value predicted by Osaki (1995a), the supercycle length near this period is expected to be insensitive to the mass-transfer rate from the secondary. If the observed change in V1159 Ori was caused by the variable mass-transfer rate, a relatively large change is necessary to reproduce the observation. Using the $\dot{M} -$ supercycle diagram in Osaki (1995a), a supercycle of 53.3 d corresponds to a reduction of $\sim 40\%$ of mass-transfer rates from what is expected for a 44.5-d supercycle. The marked reduction of the superoutburst duty cycle during this period (figure 3) also supports this interpretation.

Another observational evidence of a large period change in ER UMa stars has been reported in DI UMa (Fried et al., 1999). However, the extreme shortness of supercycles in DI UMa and RZ LMi requires an additional (still poorly identified) mechanism (Osaki 1995a), and its change may be of different nature. Another noteworthy feature in the observed $O - C$ diagram of V1159 Ori is a possible periodicity with a period of ~ 38 cycles, corresponding to ~ 1800 d, rather than

a monotonous change originally proposed by Robertson et al. (1995); this is contrary to the expected effect by decreasing heating from a hypothetical recent nova eruption on a white dwarf. The observed possible long-term period is close to those observed as possible solar-type cycles in cataclysmic variables (e.g. Bianchini (1988); Ak et al. (2001)). If such a “solar-type” cycle is responsible for the change in the supercycle of V1159 Ori, this may provide promising evidence for the presence of magnetic activity in dwarf novae below the period gap, which has usually been considered to cease, or to be markedly reduced, when the secondary becomes fully convective after crossing the period gap. Furthermore, the continuing magnetic activity may be one of the mechanisms for effectively removing the angular momentum from the binary system, by which the required high mass-transfer in ER UMa-type systems may be partly explained.

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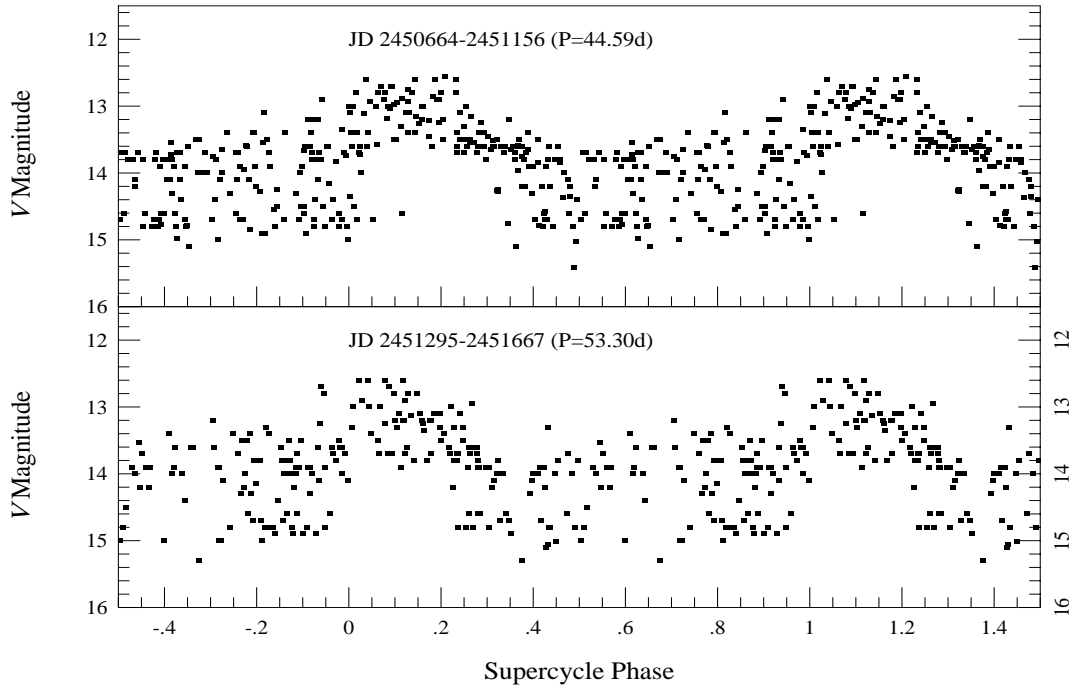


Figure 3: Folded light curves. The upper panel shows the epoch with a short supercycle length (44.59 d). The lower panel shows the epoch with a long supercycle (53.30 d) and decreased outburst activity. The duty cycle of a superoutburst (phase 0–0.45 in the upper panel, phase 0–0.35 in the lower panel) is markedly decreased in the latter epoch.